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SPECIAL FEATURES

THE AVORIO-PRASSONE KITE BALLOON
STATIC PRESSURE GRADIENTS IN WIND TUNNEL WORK
PRODUCTION AND MAINTENANCE OF AIRCRAFT
THE CLAUDEL CARBURETOR
THE LIFT OF HYDROGEN

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AVIATION AND AERONAUTICAL ENGINEERING

VOL. VIII. NO. 8

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Vol. VIII May 15, 1920 No. 8

CONSTRUCTORS and designers very often blame the wind tunnel for giving them results which are not in accordance with their tests. In their eyes, the wind tunnel is totally discredited thereby. It is however quite possible that the fault lies not in the wind tunnel, but in the model presented. This is because there is a general tendency among model makers to underestimate the accuracy of construction required in such models. In most pattern making, an error of 1/100 of an inch is of small importance. But an aerofoil with this error is useless for testing purposes.

A recent National Advisory report emphasizes the value of accuracy, and lays down definite rules for the construction of such models. Thick sections should be made of wood, thin aerofoils should be made of aluminum or some other light metal, and bodies should be made of wood. Besides accuracy, the weight of the model should be kept down. Even radiators can be duplicated with fair accuracy But, the construction of a model in order to give really valuable results should be a matter of great care and study.

This report, will no doubt achieve a useful purpose in emphasizing the value of accuracy and care in the making of scale models of aircraft for use in wind tunnel work.

Alcogas

The Bureau of Standards has recently conducted a very exhaustive test on the properties of Alcogas. The tests were made in the altitude laboratory on a 12-cyl Liberty engine, and consisted of a direct comparison between Alcogas and standard export grade aviation gasoline. A wide speed range, a wide altitude range, and a large compression range were covered. From this it is seen that he tests were very exhaustive, yet it it not quite clear whether Alcogas can be immediately recommended for use in airplanes or not. In some respects, the new gas, which is a mixture of 40 per cent alcohol, 35 per cent gasoline, 17 per cent benzol, and 8 per cent of other ingredients, is far superior to gasoline. In other respects, it is inferior.

All tests showed, at least as far as the operating staff could tell qualitatively that the engine ran more smoothly with Alcogas than with gasoline

While at ground level, the two fuels showed the same maximum brake horse power, but at all other altitudes Alcogas gave the engine a higher brake horse power.

Alcogas also showed a 15 per cent higher thermal efficiency than gasoline. Of course, in terms of brake termal efficiency, this only means 4 or 5 per cent in favor of Alcogas.

As an offset to these advantages, the test showed that as a result of the much lower heating values per lb of the new gas, the fuel consumption by weight has to be much greater than when gasoline is employed. When gasoline consumption is compared on a volume basis, this difference disappears however, the new fuel being much more dense.

From an engineering viewpoint, it is clear the new gas cannot be used indiscriminately. When a military machine is employed, the greater power obtainable in the engine by the use of the new gas will be a strong argument in its favor. In a commercial machine, where the useful loading is to be carefully considered, the greater fuel consumption by weight will be an important factor against Alcogas.

For a military machine, with a fairly large range, the same argument will apply. Just as air-cooled motors may give less performance, owing to their effective weight being increased by a higher fuel consumption, so the increasing power of the engine may be offset by a greater weight of the new fuel having to be carried.

Operators of airplanes, whether military or commercial. will ultimately learn, by experience, on what particular machines it will be best to utilize this interesting product.

Airplane Ranges

A very elegant mathematical paper by Dr. J. G. Coffin, somewhat terrifying in places, gives us a few practical conclusions regarding long range flight.

A machine should fly at a constant angle of attack corresponding to the maximum value of weight for total resistance of the machine. The range is practically the same, whether the machine flies high or low. Flying high is an advantage because the time is reduced if the range remains the same. Flying at maximum speed means a very much diminished range.

These practical conclusions are of the highest value. They are not new, but it is always an advantage to have a rigid theoretical demonstration for widely accepted rules.

Side Slip Landings

Some recent tests conducted by the chief test pilot of the Airco, indicated that with a machine flying at 70 m.p.h., and passing over a height of 75 ft., landing was made in a straight glide of 461 ft. With a side slip of 8 deg this distance was reduced to 328 ft., with a side slip angle of 13 deg. the landing distance was only 198 ft and with a steeper side slip, the distance was only 141 ft. While a side slip landing requires a good deal of skill and particularly in gusty weather may be somewhat risky, yet this decrease in landing speed of high slip is however the most effective form of air-brake yet available.

It would be interesting to have the opinion of pilots on such types of landings.

Aerial Ambulances

It is a sign of the times that an aerial ambulance based on the U. S. D-4, has been designed and constructed at McCook Field. The ambulance will accommodate the pilot, who is a medical officer, two patients, and a second medical officer The patients are to be transported in complete comfort.

This is another step towards the achievement of universal utility of the airplane.

The Avorio-Prassone Kite Balloon

By John Jay Ide

Lieutenant (j. g.), U. S. N. R. F.

The Avorio-Prassone kite balloon was designed jointly by Major Luigi Averio, Chief of the Aeronautical Division of the Italian Army, and Dr. Eugenio Prassone, Director of the Stabilimento Costruzioni Aeronautiche. It was used extensively for observation purposes in the Italian Army Venice and other cities were provided with A. P. balloons as a defense against Austrian aircraft. A number of these balloons were also built in England and used as a barrage around London.

In August, 1918, the U. S Navy brought two A. P balloons over to America, one was demonstrated at the naval air station, Rockaway, while the other was given to the Army and tested at the balloon school, Fort Omaha. Three similar balloons are being built by the Connecticut Aircraft Corp. for the Navy

The gas envelope of the A. P balloon is ellipsoidal or ovoidal (depending upon the model) with the major and minor axes differing only slightly in length. To the rear end of the gas envelope there is attached an air-filled cone serving to reduce the wind resistance of the balloon and, in conjunction with the ballonet, to maintain the shape of the gas envelope. Around this cone there are arranged three air filled fins 120 deg. apart.

The winch and basket suspensions are attached to the same points on the envelope, which in the case of the model having the ellipsoidal gas envelope has the effect of bringing the basket and main cable very close together The effect of this is to reduce the tendency of the basket to swing when the balloon is flown in very high winds. In the other model the gas chamber has been extended farther into the cone, increasing the the lifting force at the stern thereby separating the basket from the cable. By doing this a parachute basket can be used. If it is desired to bring the basket near the cable

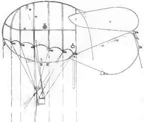


Fig. 1 Diagram of Longitudinal Cross-Section (1) Wind Scoop to Ballonet (2) Wind Scoop to Rudder Cone and Upper Fins (3) Air Valve on Cone. (4) Air Inlet Ballonet to Fin. (5) Ballonet Deflation Sleeve. (6) Rudder Deflation Sleeve. (7) Air Inflation Sleeve For Cone and Upper Fins. (9) Gas Inflation Sleeve (10) Valve Adjustment Sleeve. (11) Manometer Sleeve. (12) Manometer Removal Sleeve. (13) Gas Valve. (14) Rip Panel. (15) Trajectory Bands (16) Rope Reinforcing Bands. (17) Air Inlet to Cone and Upper Fins.

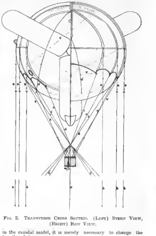


Fig. 2. Transverse Cross Section (Left) Stern View, (Right) Bow View.

in the ovoidal model, it is merely necessary to change the lengths of the suspension ropes.

Envelope

The gas envelope (Fig 1) is composed of gores (as in the case of airships) and the spherical form is maintained by wide and strong trajectory bands (15) ending at the vertices of the catenaries, thus reinforcing the rigging points.

The ballonet seam line is directly above the catenaries and parallel to a line connecting the terminal rings of the rigging. Therefore, all the outer fabric on the under side of the balloon, the part that rests on the ground when bedded down, contains only air The tension due to the lift and to the action of the wind, on the other hand, is all concentrated in the terminal rings and is transmitted to the cable through the suspension.

The catenaries are of steel wire cable 5 mm. in diameter, with a tensile strength of about 3960 lb while the suspension ropes, made of hemp, are 12 mm in diameter, with a tensile strength of about 2640 lb

Three-ply cotton fabric, rubberized between the plies, is used for the gas envelope.

At the bottom of the gas chamber there is a diaphragm forming the ballonet when the balloon is not longer full of

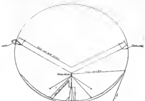


Fig 3. Automatic Gas Valve Gear

gas (in descent) Air is admitted into the ballonet by means of the scoop (1), the ballonet also communicates with the bottom fin through the opening (4) An automatic gas valve (13), placed near the equator, is operated by means of small non-stretching metal lines attached to the fabric of the diaphragm.

On top of the envelope is the ripping panel (14) Operating this uncovers a series of elliptical holes for the escape of the gas. The ripping cord runs through the gas chamber, out the port side of the envelope and thence to the car

Cone and Fins

The cone and fins are filled with air which enters the lower fin through the scoop (2) and the opening (4) from the ballonet The openings (17) between the lower fin and the cone are fitted with fabric valves allowing the air to pass from the fin to the cone but not back again. This allows the cone and upper fins to be inflated by a pump through the air inflation sleeve (7), thus obviating swaying at the beginning of the ascent, while the lower fin remains deflated until acted upon by the wind during the ascent.

The fabric valve (3) on top of the cone is so adjusted that it begins to open at a lower pressure than the gas valve. The expansion of the gas before the gas valve opens expels extra air from the cone and fins at the same time as from the ballonet.

On mooring, complete air deflation is obtained in a very few minutes by opening the proper outlets.

Two-ply rubberized cloth fabric of very fine texture is used for the cone and fins.

Suspension

The cable suspension (Fig 2) consists of twelve ropes which start from the vertices of the catenaries on the envelope and come together in two groups, right and left, each group terminating with a metal ring The two rings are joined together by means of a ring on a steel rope to which the main cable is attached.

Two further rings are also attached to those mentioned above. If the basket is near the cable one of these rings carries the ropes for the central sand bag attachment and also the central handling guys, while the other takes the two forward suspension ropes of the car Otherwise, the sand bag

Fig. 4 Gas Valve of A. P. Kite Balloon

Fig. 5 Inflation of an A P Balloon

attachment and handling guys are secured to the two rings, the forward car suspension ropes running to the envelope

The car suspension consists of eight ropes of which the four side and the two stern are attached to the terminal rings of the catenaries on the envelope If the basket is near the cable the two bow ropes are secured to the two rings terminating the cable suspension, as noted in the preceding paragraph If not, the two bow ropes are attached to the catenary rings The car suspension ropes are marked with colored thread and are joined to the car ropes bearing the same color and mark numbers All suspension ropes, cable and car alike, are fitted with cleats so that their lengths may be adjusted.

Gas Valve Adjustment

During the inflation of the balloon the closed manometer sleeve, about 6½ ft long, is kept drawn out, and when it begins to fill inflation is stopped It is thus possible to be sure that the balloon is full and the adjustment of the valve (Fig 3) can be proceeded with, setting the knot of the line of the fabric cone so that the valve will open at the proper pressure As the lines made are of metal, once the adjustment is made they should not stretch sufficiently to affect the operation of the valve

Gas Valve Construction

A balloon, when let up slowly is at earth potential in a field of very different potential, thus establishing a large potential difference between the balloon and the surrounding air Under these conditions sparks and "corona" discharges occur from the surfaces of the component parts of the balloon, especially from projecting points The flow of electricity from the balloon to the surrounding atmosphere gives rise to discharges, which although silent, are capable of producing the ignition of a mixture of hydrogen and air.

FIG. 6. A. P. BALLOON READY FOR ASCENT

It was considered advisable, therefore, to adopt a gas valve having no metal parts, in addition to taking other precautions enumerated below. The valve used in the A. P. balloon (Fig. 4) is a wooden one of the type used in spherical balloons, suitably modified. The seat is of wood and metal wing nuts are not used, the ring being attached directly to the fabric by means of lacing.

Steel springs are replaced by rubber cords which render the adjustment practically automatic, since each cord passes through a small hole in a wooden cleat fixed to the flat part of the valve. When under tension in the direction of action the cord cannot be dragged out of its holes, even by pulling hard, owing to the swelling of the end. To adjust the rubber it is sufficient to pull it simultaneously on both sides of the holes, when it will run easily.

The rubber cords are protected from atmospheric effects by being enclosed in rubber fabric, gathered to allow stretching. Fabric also protects the wood of the valve.

Electrical Connections

As the result of special investigations which were made on the subject of electrification of balloons, it was found desirable to keep the envelope insulated, allowing it to take up the potential of the surrounding air, while keeping the car at earth potential.

This is obtained in the A. P. balloon by:

(1) Eliminating all metal connections, both between the envelope and car and between the envelope and mooring cable.

(2) Carefully insulating the envelope by covering all hemp suspension ropes with rubberized fabric and insulating the valve handline and rip line, which run to the car, by means of silk cords.

(3) Using a wooden gas valve fitted with rubber cords.

(4) Suspending one discharger just forward of the valve and another from the top of the cable.

The basket is attached to the main cable and therefore to the earth by means of the telephone cable.

Advantages of the A. P. Balloon

Following are enumerated the principal advantages of the balloon:

(1) Great stability, rendering possible accurate observation in a wind of 50 m.p.h.

(2) Low wind resistance, enabling lighter cable to be used than with other types, and therefore greater height to be attained.

(3) Reduced yawing of the balloon due to gusts at the beginning of the ascent and on landing owing to the small moment of inertia.

(4) Smaller target offered than by other types of balloons of similar capacity. When moored, a smaller exposed surface is presented to the wind.

(5) Maintenance of envelope shape assured by spherical form, simplicity of rigging and arrangement of the air chamber. On this account and by reason of its small static couple and low projected area, a great hauling down speed can be attained, of obvious value in case of attack by enemy aircraft.

(6) Strength and gas tightness of envelope increased by use of three-ply instead of two-ply fabric.

(7) Notable economy of gas in comparison with other types of balloons, as (a) for the same height and useful load the volume required is less, and (b) it is always possible to let the balloon up without completely filling it with gas, the form being maintained by the air chamber closed by its special valve.

Long life of the suspension ropes due to the fact that the rigging is fixed. The ropes of running rigging quickly wear out through chafing in the rings.

(9) Special precautions taken to avoid possibility of electric discharges which might ignite the gas by using wooden valve, insulating envelope, etc.

(10) In case of breakage of the cable the balloon can be handled like an ordinary free balloon.

CHARACTERISTICS OF THE A. P. KITE BALLOONS

Capacity	26844 cu. ft. (700 cu.m.)	28250 cu. ft. (800 cu.m.)	31760 cu. ft. (900 cu.m.)	37080 cu. ft. (1050 cu.m.)	38840 cu. ft. (1100 cu.m.)
Diameter	32 ft. 8 in.	33 ft. 8 in.	34 ft. 11 in.	37 ft. 8 in.	37 ft. 8 in.
Length	44 ft. 8 in.	53 ft. 1 in.	55 ft. 11 in.	55 ft. 4 in.	59 ft. 0 in.
Total weight of envelope including catenaries, trajectory and mooring bands	650.4 lb.	705.5 lb.	748.8 lb.	818.7 lb.	859.8 lb.
Mooring lines attached to envelope	28.7 lb.	28.7 lb.	28.7 lb.	28.7 lb.	28.7 lb.
Cable suspension with cable attachment rings, central sand bag and handling guy attachments	38.7 lb.	38.7 lb.	41.8 lb.	40.8 lb.	46.8 lb.
Car suspension	15.4 lb.	15.4 lb.	15.4 lb.	15.4 lb.	15.4 lb.
Cotton handling guys	86.1 lb.	86.1 lb.	86.1 lb.	86.1 lb.	86.1 lb.
Gas valve	11.0 lb.	11.0 lb.	11.0 lb.	11.0 lb.	11.0 lb.
Car	70.5 lb.	70.5 lb.	70.5 lb.	70.5 lb.	70.5 lb.
Total	914.8 lb.	956.8 lb.	998.8 lb.	1049.7 lb.	1097.8 lb.
Gross gas lift at 0°C. and 760 mm.	1964.1 lb.	2081.1 lb.	2341.8 lb.	2738.7 lb.	2881.5 lb.
Net gas lift at 0°C. and 760 mm.	1033.3 lb.	1144.2 lb.	1858.1 lb.	1680.0 lb.	1783.7 lb.

Static Pressure Gradients in Wind Tunnel Work

By Dr. J. G. Coffin

Director of Research, Curtiss Aerodynamical Laboratories

In aerodynamic wind tunnels the air is sucked through the tunnel by a propeller or fan. There must, therefore, be a gradual increase in static pressure along the air stream from propeller to inlet section. By employing the static pressure openings of a Pitot tube, which has been shown to be a very reliable instrument for this purpose, and using a sensitive differential manometer, these pressures can be easily measured at several points along the tunnel, especially in that portion where the models are set up. The results of these measurements in the experimental portion when plotted usually give a curve which is practically straight, as shown in Fig. 1. The

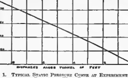


FIG. 1. TYPICAL STATIC PRESSURE CURVE AT EXPERIMENTAL PORTION OF WIND TUNNEL

slope of this curve at any point is called the pressure gradient and is properly expressed as lbs./sq. ft./ft. Mathematically, it is $\frac{\Delta p}{\Delta x}$ where x is a distance measured along the axis of the tunnel.

There is seldom any question of pressure gradients at right angles to the axis of the tunnel as in any such installation worthy of good repute there should not be any. In other words, over the central area at right angles to the tunnel axis at the experimental section the static pressure should remain constant to within at least two tenths of the tunnel diameter from the limit of the air stream.

Even if there were a pressure gradient at right angles to the tunnel axis its effect on drift would vanish and its effect on lift would vanish if it were symmetrically distributed around the tunnel axis. In any case, lifts are usually so much larger than drifts any unbalanced lift forces due to unsymmetrical static pressure distribution would be negligible. In the large Curtiss Tunnel the static pressure is constant over the whole cross section and is the same as that obtaining in the room.

The measured drift on a model can then be considered to be made up of two parties:

(a) The drift, D, due to dynamic pressures and friction, and

(b) A fictitious drift, d, due to the unbalanced resultant effect of the static pressure acting on the surface of the model.

The first part, D, is that whose value is desired and corresponds to that which would obtain if the model were carried through the open air at the same speed as that at which the measurements were made; the second part, d, is inherent in the design of the tunnel and must be eliminated to obtain correct results.

This static pressure correction can attain surprisingly large values, especially in the enclosed type of tunnel (N. P. L. type), in some cases running as high as 25 per cent. of the total measured value, but it is, however, much less serious in the Eiffel type of tunnel and in certain cases can be entirely eliminated or even become reversed in sign.

In the large Curtiss tunnel, not only is the static pressure constant across the experimental section of the wind stream as mentioned above but has been found to be absolutely constant throughout the whole experimental chamber. This property, which is the result of our design, eliminates entirely the necessity for the corrections for static pressure and is very convenient. It was attained by a proper dimensioning of the inlet and outlet diameters in the experimental chamber.

In the Four Foot Curtiss tunnel the pressure gradient is about .071 lbs./cu. ft. at 60 m.p.h. In the Navy Tunnel it is about .0236 lbs./cu. ft. at 40 m.p.h., which corresponds to .0531 lbs./cu. ft. at 60 m.p.h. It has been found that the pressure gradient at 1 m.p.h. is practically independent of the air speed at which it was measured, hence it is convenient to determine it at as high a speed as possible as the percentage accuracy of the determination is thereby increased. It has been found also that the presence of the model changes but little the value of the pressure gradient determined in the absence of the model. The static pressure can be assumed for all practical purposes to vary as the square of the wind speed. It should also be noticed that as the static pressure measurements are to be applied as a correction, the accuracy of their determination need not be better than from five to ten per cent. The theory of this correction is quite simple and is usually carried out graphically. A short resume of this theory is given below.

In Fig. 2 let the static pressure be known at every point along XX', there being no variation at right angles to this axis, as mentioned above. This static pressure acts normally to every element, dA, of the surface, S. The element of force acting upon dA and normal thereto is p dA. Let the angle between the normal to the surface at this point and the axis of the tunnel be α then the axial component of the force on this element is $p\,dA \cos \alpha$. At the rear, α is greater than

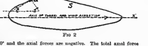


FIG. 2

90° and the axial forces are negative. The total axial force whose value is desired is, therefore,

$$d = \int\int_s p \cos \alpha \, dA \qquad (1)$$

There are several cases for which this formula can be somewhat modified.

(1) In case a body is one of rotation about the tunnel axis (Fig. 3a) the general intergral (1) reduced to

$$d = \int 2\pi y \, ds . p . \cos \alpha = 2\pi \int p \, y \, dy \qquad (2)$$

$$\text{as} \quad \cos \alpha = \sin \beta = \frac{dy}{ds}$$

(2) Cases similar to a uniform strut section placed perpendicular to the wind. (Fig. 3b)

If ds is an element of the contour of the cross section then dA per unit of length $= ds$, and the integration being made around the contour, equation (1) becomes

$$d = \int p \ dy$$

and for length, l, it becomes

$$d = l \int p . \, dy \qquad (3)$$

(3) Another expression for this integral is easily seen to be true by considering the body to be made up of sections as illustrated in Fig. 4, and is

$$d = \int \int p . \, dA \qquad (4)$$

where A is the cross sectional area at right angles to the tunnel axis at the point where p exists.

Except for spherical bodies, or bodies whose shape is determined by mathematical curves, these integrals can seldom be carried out mathematically and the integrations must be made graphically by a "step by step" process which as a rule involves considerable calculation and time and are practically impossible of application to bodies of complex form such as complete airplane models with which we have found there is an appreciable correction.

The theory and method of application outlined below show the possibility of simplifying these computations and making the corrections possible even for airplane models. This simplification is based upon the fact that the pressure gradient, in most tunnels that I am acquainted with, is practically constant in the experimental portion. For example, Fig 1 shows a typical static pressure curve for an enclosed type tunnel*. Even when this gradient does vary slightly it is very easy to take an average value, approximately the value which exists at the center of gravity of the body under test.

If p is a scalar point function whose value is known for all values of x and is independent of y and z, that is, is constant over the cross section at right angles to the tunnel axis, the following integration theorem is true, where the volume integral is taken throughout the volume of the model and the surface integral is taken over the surface enclosing this volume**.

$$\iiint_{vol} \frac{dp}{dx}\, d\,(vol) = \iint_{s} p \cos (nx)\, dA \quad (4)$$

Let us now assume that the pressure gradient is constant, that is,

$$\frac{dp}{dx} = a$$

or what is the same thing, that the pressure curve is a straight line whose equation is

$$p = ax + const \quad (5)$$

the volume integral becomes with this value for p

$$\iiint a\, d\,(vol) = a \iiint d\,(vol) = a \times volume$$

and as the surface integral is the one whose value it is required to evaluate, we obtain finally for the correction

$$d = pressure\ gradient \times volume\ of\ model \quad (6)$$

in other words, this is a strict mathematical proof that the static pressure gradient produces an effect akin to a buoyancy correction. The result is nothing more nor less than Archimedes' principle. As pressure gradient is by definition — its dimensions are

$$\frac{dp}{dx}$$

$$\frac{Force/Area}{Length} = \frac{Force}{Volume}$$

* Aviation, October 15, 1918, p. 357

** A. G. Webster, "Theory of Electricity and Magnetism," p. 63

FIG. 3 ELEMENTS OF AREA FOR (A) BODIES OF ROTATION, AXIS ALONG THE WIND; (B) BODIES OF CYLINDRICAL SHAPE, AXIS OF CYLINDER ACROSS THE WIND

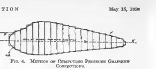


FIG. 4. METHOD OF COMPUTING PRESSURE GRADIENT CORRECTIONS

and when multiplied by a volume as required in equation (6) it gives a force as it should.

The great value of this method consists in the fact that it is usually very easy to obtain the volume, either by immersion in water or by planimeter, for example, and the mere multiplication of the volume by the known pressure gradient gives the value of the correction. This way of looking at it also shows that the correction is independent of the orientation of the body just as the buoyancy of an immersed shape in a liquid is independent of its position relatively to the vertical.

As an example of the application of this method to a specific case, let us consider the correction to be applied to the 9"x3" strut (Navy No. 1 Strut) tested at the Navy Yard by Dr Zahm*

By planimeter, area cross section=19 2 sq in.
Length of Strut =60 0 in.
Volume=60x19 2=1152 cu. in. =0 667 cu. ft.
Pressure Gradient at 40 m.p.h. at
Center of Gravity of strut=

$$\frac{.0034 \times 62.43 \times 12}{9 \times 12} = .0236\ lb./cu.\ ft.$$

Correction by equation (b) =
667 x 0236 = 01573 lb
Correction as published by Dr Zahm = .0158 lb

The agreement is very satisfactory and shows that this method usually can be applied with perfect safety

When it is considered that the presence of the model probably does modify to some extent the distribution of static pressure it is seen that the correction by whatever method computed is inherently not very precise and as mentioned above, results which are within 10 per cent of the true correction are amply good enough.

With dirigible models or even models of complete airplanes the volume can easily be obtained by immersion and weighing of the overflow so that even complex shapes are easily taken care of.

The absence of any pressure gradient in the Eiffel type of tunnel as modified in the Curtiss tunnel is now seen to be an extremely valuable property as it entirely eliminates the necessity of these corrections and accompanying labor No difference of static pressure greater than two or three hundredths of a millimeter of water were detected between any two points in the large experimental chamber of the Curtiss tunnel. This statement includes points both within and without the air stream.

* Loc. Cit.

A Letter

EDITOR, AVIATION AND AERONAUTICAL ENGINEERING:—In AVIATION for April 15, 1920, Dr. J. G. Coffin describes a pressure gauge used in his laboratory which is only a mechanical modification of the one invented by me in the summer of 1916 and described in AVIATION for Nov. 1, 1918. In both, we use the Krell system. In mine I alter the sensitivity by changing the angle of the slope by means of a screw, while Dr. Coffin does it by revolving the glass tube about a horizontal axis. In mine I get the head by moving the tube along the slope; Dr. Coffin gets the head by raising or lowering the tube on a standard. The basic idea, namely to alter the sensitivity by changing the angle of the tube to the horizon, and to move the tube so as to keep the meniscus at one point in the tube, is mine and was disclosed as long ago as Nov. 1, 1918. Dr. Coffin thinks this idea so good that he speaks in great praise of it, but he gives me no credit for originating the idea. In fairness to me you ought to call the attention of your readers to this fact.

A. H. MERRILL.

Characteristics of Design Effecting Production, Operation and Maintenance of Aircraft*

By Maj. Percy Bishop

The advent of the use of aircraft for purposes other than warfare will involve the appearance of several additional aspects into the already numerous considerations which have to be applied during the evolution of the design of an aircraft.

During the recent war, designers were called upon to produce designs in which performance and maneuverability were the foremost considerations, and sacrifices of other factors, including safety and stability, had to be made in order to attain supremacy in these directions. It is true that during the latter stages of the war matters concerning ease of production, the use of alternative materials and accessories, and facilities for maintenance did receive a certain amount of attention, but in view of the speed at which designs and production had necessarily to mature, the amount of thought which could be given towards such considerations was very limited.

Today the aspects are considerably changed, and the following notes are prepared with a view to emphasizing the importance of those factors which in the past have been restricted, but which in the future will tend to take precedence among the characteristics of aircraft. In these notes it is not proposed to touch upon the relative importance of safety, performance and stability, but rather to deal with the characteristics which interest those constantly engaged with aircraft, whether they be concerned in manufacture, operation, maintenance or repair.

There is no doubt that aircraft suffer far more depreciation when on the ground, especially when subjected to transport and re-erection, than when kept in continual flying use. In future possibly the majority of this country's output of aircraft will be exported, and consequently the above conditions will apply, not to isolated cases, but to a majority, thus emphasizing the necessity of the design being so contrived that provision is made to withstand such conditions.

Apart from this, a little consideration on the part of designers and draughtsmen will very considerably ease the lot of all concerned in the production of the machine. Such consideration will always assist in reducing the cost of manufacture, accelerating production, and evolving a more serviceable machine.

Experience during the war has shown that a great saving can be effected by very careful consideration being given to preparation of detailed drawings, so as to avert such an excessive amount of alterations as attended all designs during the early stages of manufacture.

Again, nearly all failures in the air are traceable to detail faults, and several otherwise excellent designs of airplanes have been doomed owing to detail defects.

The various aspects from which improvements in design appear to be beneficial are dealt with in the following order, which covers the stages through which the aircraft passes from its conception to its "write-off" —

(1) Preparation for manufacture.
(2) Manufacture and assembly.
(3) Inspection.
(4) Storage, packing, and transport.
(5) Operation and maintenance.
(6) Repairs and replacements.

Preparation for Manufacture

The work involved in the preparation of a design for manufacture is chiefly connected with the design of details, and with the production of drawings. It may be of interest to deal briefly with general drawing procedure, especially in regard to the information which should accompany all drawings in order to facilitate the production of the part or component concerned.

In the first place, the drawing should be regarded as a complete specification of the article required. It should contain the following information:—

1. All necessary dimensions, with permissible errors in manufacture, including accurate development in the case of complicated bent-up parts.
2 Particulars of the material from which the part is to be made
3. The sequence of operations necessary for the production of the part.
4. Details of any heat-treatment which may be necessary at any stage of the work.
5. Protective requirements to prevent deterioration due to atmospheric conditions.
6. Identification marks in order that the part may be identified during and after manufacture.
7 The component or type of aircraft on which the part is used.

Each drawing should be on a separate sheet of convenient size.

Many designers do not even now consider all the above information essential, and do not include such items as operations and protective requirements. Their view is that the shop staff know better how to produce the part than the designer or draughtsman, but although this is undoubtedly true in many instances today, it is contended that the process of manufacture should be considered by the designer at the time of evolving the design; and that if the design is so arranged as to require a specific method of manufacture, the particulars ought to be stated on the drawings.

Admitting the necessity for means of identifying parts, partial assemblies and components, it is essential that a suitable numbering scheme for drawings be adopted. The production problems of automobile engineering are very similar to those of aircraft, and it is almost universally agreed that the adoption of one single series of numbers for components, parts, or even pieces of parts, is the most satisfactory method of identification This system involves a separate drawing of each part and of each piece of a part. At first sight this may seem to be a cumbersome procedure, but it proves of great assistance to those engaged in production, where attention has at certain stages of manufacture to be paid to each individual piece separately.

Take for example the case of a built-up sheet metal fitting made up of two or more pieces. For this we shall require:—

1. A drawing of the complete part as required for erection; and
2. A drawing of each piece comprised in such a part.

It is assumed that these drawings are produced on the lines indicated above, and that the information they afford is more complete than is now usual.

Such drawings will have other advantages besides being more generally useful during actual manufacturing operations. The work of ordering and laying out will be much simplified, as the accurate development of parts or pieces can be set out in such a way as to obviate the tedious operation of laying-out in the shops by staff, whose facilities and capabilities for the geometrical and mathematical work required, can hardly compare with those of a trained staff continually engaged in such work in the drawing office.

Further, the drawings will be of material assistance to staff engaged in the stores and despatch departments. The drawings of parts, partial assemblies, and components, should each contain their respective schedules, as such information is necessary to complete the specification of the article represented. No further schedules will be required, and this is particularly advantageous in eliminating the liability of errors during the incorporation of modifications which involve alterations to both schedules and drawings. Such modifications are inevitable during the experimental stage of aircraft manufacture. The system also has the advantage that it leads automatically to standardization, whether of pieces, parts, or components.

Considerable economy of material, of machining, of labor,

*Paper read before the Royal Aeronautical Society of Great Britain. (Excerpt.)

and of temper, can be effected in the preparation of detailed drawings by calling for current available materials, and utilizing, as far as possible, standard sizes of bars, sheets, and tubes. Each detail should be so arranged that it may be produced economically from such standards. If the requisite sizes of bars, sheets, etc., be named on the drawings the information will be useful from a buying and store-keeping point of view.

This point may be made clear by an example or two. For instance, parts such as turnbuckles, forked-ends, engine valves, spindles, etc., which are usually produced in quantity on automatic machines, should be preferably arranged so that the maximum diametric dimension falls just inside the standard bar diameter. This will reduce to a minimum the removal of redundant material for the whole length of the part before the forming is commenced, and will thus do away with waste of material and needless wear of cutting tools.

Another example is that of a tank, in which, if the maximum width of sheet from which the shell, the ends, or the baffles, are made, falls just outside the standard size of sheet, the result is either a larger sheet being cut uneconomically, or the introduction of an additional seam in the construction of the tank.

Propeller laminae, long spars, longerons, and struts, also frequently give rise to difficulty in manufacture owing to timber being unavailable in the required dimensions. There is then no alternative but to introduce joints, which are expensive to make and unsatisfactory in themselves.

The drawings should also specify carefully the permissible limits of error in manufacture, whether these are required to safeguard the strength of a part or to secure interchangeability. In determining such limits consideration should be given to tolerances necessary for the various manufacturing operations. In the case of interchangeability, additional consideration is necessary to provide sufficient "allowance" for error in gauge manufacture; and in some cases yet further allowances must be made for small errors in the manufacture of master gauges. This matter is of particular importance in the case of hinges or joints at the junctions of components where interchangeability is essential. Frequently the dimensions in these cases are large, and errors in manufacture are correspondingly increased. In such cases it is not sufficient to arrange the limits so that the parts shall in theory assemble where one part is on the high limit and the other on the low.

In the case of wooden parts allowance must also be provided for shrinkage of timber and distortion.

The whole question of limits is very involved, and can only be briefly touched upon in this paper, but in order that the drawings may be complete, the statement of limits must be such as to constitute legal evidence of the requirements, both on the part of the supply contractor and as affecting the manufacturing or erecting shop staff when payment is made on a piece-work basis.

Manufacture and Assembly

The cost of production has received little consideration in the past as a factor in the design of aircraft, but with the development of aircraft for commercial purposes it has been realized that serious attention must be given to it.

The phases passed through since the conception of heavier-than-air flying machines make an interesting study. Most of the pioneers of flying had but limited resources for making and building their experimental machines. Accordingly the fittings they designed were generally arranged in the simplest possible way, and produced at the least expense.

Later on, when flying became more general, experiments were no longer embarrased by lack of financial assistance. Designers then began to use the best material and labor available, and concentrated their attention on reducing resistance and weight to a minimum; thereby improving performance, without eliminating any of the necessary requirements for safety.

It is perhaps fortunate that the development of aircraft passed through such a stage so early in its career, especially as the burden did not fall on the industry itself. It enabled the essential qualities combining to ensure safety and good performance to be developed very rapidly.

The next phase is that of a compromise, and represents the one which interests the industry today, the problem being to reduce the cost as far as possible by designing to suit manufacturing facilities generally, without any retrogression from the advance arrived at in safety and performance.

The extensive use of fittings made from sheet metal, which can be punched out correctly to shape, and which require but few subsequent operations to complete manufacture, is undoubtedly a progressive stage towards this end. Such a method of production is considerably cheaper than that of using forgings and stampings, with the unavoidable subsequent machining. Until quite recently there was much prejudice against the use of sheet metal pressings, this arose from the assumption that the punching operation produced cracks of a dangerous character upon the sheared edges, but it has been found that this danger can be avoided by taking certain precautions, namely, the trimming-up of all edges where stress is likely to occur, and the removal of small cracks which might develop and cause trouble. For small holes the punching operation should be always followed by drilling and reamering.

In adopting such a method of production the standardization of shapes of parts, or pieces of parts assists very materially. The cost of die-making and setting-up represents a very high percentage of the total cost, and consequently the number of shapes required should be kept down to a minimum. This can be achieved by so arranging the shape of a blank that other shapes may be cut from it by means of another shearing operation to cut away the redundant portion.

Another feature which perhaps has not been realized is the fact that the manufacture is simplified in the case of "right-hand" and "left-hand" parts. The blanks are always flat at this stage of manufacture, and the subsequent bending operation will determine the "hand." In the case of stampings, two dies are usually necessary, which not only involves setting up the dies twice, but also duplicates the number of jigs and subsequent operations.

The use of sheet metal fittings has the further advantage that the sheet from which the blanks are punched serves excellently as the locating portion of a jig for subsequent operations on the blank, such as drilling, etc.

Another important advantage of sheet metal construction which is particularly evident today is that it suits manufacturing conditions, no matter whether large quantities of the same part are required or merely the number necessary for one experimental machine. If the quantity does not justify the making of press tools, the blanks can readily be "nibbled" out from sheets at extremely low cost.

The combination of a number of blanks bent to desired shapes and connected together by riveting, welding or brazing, is quite a cheap method of manufacture. In designing such fittings care must be exercised to ensure that the process of normalizing the material to remove strains, caused through bending or welding, is capable of being carried out, without involving prohibitive distortion of the final shape required.

From the manufacturer's point of view standardization is of the utmost importance, and too much stress cannot be laid on the necessity of giving it the utmost consideration in the early stages of the design of detail parts. Holes, screw threads, angles, tapers, and even radii of corners (where a machining operation is required), should be of standard dimensions, and the minimum variety of such sizes consistent with efficiency should be called for. This will result in limiting the number of sizes of drills, taps, dies, broaches, reamers, gauges, spindle tools and cutting tools generally, and also in some cases in an economy of setting-up operations.

The average number of tools and gauges required when manufacturing any particular design today, is unnecessarily high, and can be materially reduced without detriment to the efficiency of the machine itself.

In the design of covered components, one of the most prevalent difficulties which occur in manufacture is that of distortion, and it essential that the structure should receive consideration from this point of view in the design. The strains of fabric doping, initial tension in bracing wires, shrinkage of timber, and bedding down of metal fittings on to timber, all tend towards distortion, which hampers quick erection, destroys interchangeability, and may well result in rendering the component unserviceable.

One of the greatest difficulties of erection experienced today occurs at the later stages of assembly, and that is the large extent of hand fitting which is necessary in the fitting of cowlings, connecting up of pipings, controls, and the fittings of accessories generally. This is due to the fact that drawings are usually not considered necessary for such parts, and the design is left to the shop staff to decide at the time of erection. The contention is that complete drawings should be made of all parts, and more particularly that the operation of assembly should then receive attention. If the dimensions of such parts are difficult to determine on paper, the use of "mock-ups" should be resorted to for this purpose. This practice also usually tends to the devising of more satisfactory arrangements, as regards both erection and functioning.

It is possible to incorporate in the design many other features which will simplify the erector's work and permit of increased accuracy in truing-up. As instances, fittings may be made self-aligning by means of universal joints or in other ways; strut fixings, wiring plates, etc., may have their securing pins arranged to hinge in the most convenient plane for lining up, and multiple connections (hinges, for example) may be arranged to register on one of their number with ample clearance in the remainder.

Inspection

The future of British aircraft depends very largely upon the maintenance of their acknowledged existing supremacy as regards both safety and reliability. This position has been won, firstly by sound design, both structural and aerodynamic, and secondly by ensuring that the actual aircraft comes into existence and continues to exist in the form intended by the designers.

It is clear that the first requirement necessary for carrying out any examination is adequate access to all important members and organs of the aircraft.

One of the peculiarities of aircraft design is that the performance very largely depends on securing clean, uninterrupted exterior surfaces, and on the streamlining of shapes which would otherwise increase head resistance; thus all structures and mechanisms tend to become hidden from external view by cowlings, coverings, fairings, etc. There is, however, no reason why such coverings should not be made easily detachable, or other provision made for purposes of inspection, without incurring any appreciable increase in head resistance.

It is realized that in the special case of planes this procedure is in practice prohibitive. When doubt arises as to the airworthiness of a plane which has been a long time in store, or has been transported from place to place, it may be necessary to strip and recover the component.

In any case, however, the more vital parts should be easily accessible, so that periodic examinations and adjustments may be carried out. Such inspections are demanded daily by the Air Navigation Regulations before passenger flights may be made, and provision should therefore be made to enable the ground engineer to satisfy himself of the safety of the aircraft in the shortest possible time.

One of the most important items in construction is the control mechanism, which should be carefully studied in this connection. Where controls are carried inside planes, doors or windows should be provided to view all pulleys, levers, and connections, in order that correct alignment, security of attachment, and wear of cables can be safeguarded. Such inspection doors or windows should be so arranged that the whole of the run of the cables can be examined through them, in order to see that they run clear of obstacles such as ribs, struts, cross-bracings, etc.

To facilitate the attainment of these conditions sight holes or gaps should be employed to ensure —

(a) The correct bedding of struts in sockets or on to other members;

(b) Sufficient length of engagement of screwed parts;

(c) The correct positioning of internal blocks in hollow built-up spars or other main members, as for example those constructed on the "McGruer" system.

Unless some such provision be made it is impossible, once the parts have been erected, to discover if these points have been attended to.

Particularly in the case of the power plant installation, periodic inspection is essential on account of the prevalence of leaks in petrol, water, and air systems, and the breaking or "shorting" of ignition wires caused through vibration or landing shocks. It is therefore absolutely necessary that the question of accessibility should be given the utmost weight. Improvements, in the form of quickly detachable cowlings, provision of sufficient inspection doors locally to petrol cocks and connections, or arrangement of the pipe lines or run of engine controls in such a way that they may be easily inspected, are essential.

Whilst dealing with the question of installation piping, it appears opportune to emphasize the importance of marking the various pipes for identification purposes. There is a standard method of painting the various pipes to denote whether they are for oil, water, air, or petrol, viz., red for petrol, yellow for compressed air, black for oil, blue for water, white for air speed tubing, and yellow and red for air pressure for petrol feed—and such first-sight distinction is an invaluable asset when checking a complicated installation system.

The work of an inspector can also be facilitated by the elimination as far as possible of such processes as welding, brazing or soldering, especially where the strength or security of the parts so treated is important. It is obvious that, after the operation has been performed, such a process cannot be certified as having been correctly carried out. Moreover, a selective test to destruction is not considered a sufficient guarantee, owing to the great degree of variation which can occur in such processes. Even with the "dip brazing" method the retention of the correct analysis of the brazing metal cannot be guaranteed, as the difference in the melting temperatures of the ingredients causes the zinc to evaporate away faster than the copper, so that even with frequent additions of zinc, and check tests at each addition, the constitution of the bath cannot be regarded as even approximately uniform.

A difficulty experienced in checking the truth of erection of an aircraft is to find datum surfaces or points from which to begin the series of check measurements. The provision of a horizontal cross and longitudinal member at some convenient point in the structure will serve to establish a level in both directions, and allow measurements to be based on this datum.

Storage, Packing and Transport

The difficulties encountered in the storage, packing, and transport of aircraft components, and the consequent damage experienced during recent years, have been very great. The principal reasons are —

Firstly, the fragility of the parts necessitating the most careful methods of handling, packing and storing.

Secondly, the sizes and awkard shapes of the components and parts demand a large amount of space, both for storage itself, and as adjustment room for manipulation in the store; and

Thirdly, the difficulty of supporting the component or part when stored or packed to prevent damage due to chafing or distortion.

To meet such contingencies there appear to be two alternatives, on the one hand to provide special packing cases for each of the components or parts, which would render them immune from such damage; or on the other hand, to relieve the situation by refraining from the use of such fragile or large components, and make special provision in the way of supports, etc.

The first alternative would obviously be impracticable as a general measure, on account of the excessive cost involved in making the cases, although in certain cases such as engines, propellers and instruments, such practice is unavoidable. The second alternative can, however, be taken advantage of to a large extent, provided consideration is given to the question at the time of design.

The average covered component is incapable of being stored, packed, or transported, without receiving injury of some nature, owing to the impossibility of supporting it at favorable positions of its structure.

The addition to such a component of some form of projections by which it could be supported or secured would be invaluable from a transport and storage point of view. In addition, the designer would then know definitely the conditions to which component would be subjected, and could arrange the local members of the structure to take the corresponding stresses.

The adoption of permanently built-up structures such as

undercarriages, V-struts, cowlings, and fairings, should be avoided as far as possible to meet this end, and such forms should be superseded by structures which could readily be dismantled to convenient sizes and shapes for storage and transport purposes.

The limitation of sizes of components should be governed by the conditions of existing methods of transport, where such restrictions as heights of bridges, lengths of trucks, lorries, or trailers, have to be complied with. Considerable difficulty in transport has already been experienced in this direction, and the existence of prohibitive sizes of components has frequently led to extensive trouble and excessive cost in arranging transport. It becomes evident, therefore, that large components such as planes and fuselages should be capable of being dismantled to a more convenient size. In the case of planes with long chord measurements this could be effected by provision of detachable trailing portions, and long planes or fuselages could be made in sections with suitable jointing arrangements.

The use of detachable projections, such as levers and king posts, on covered components should also be encouraged with a view to meeting storage and transport facilities.

The storage of complete aircraft has been facilitated considerably by the development of folding wing arrangements, and it is encouraging to see that this practice is now being extended to small aircraft.

The deterioration of tires during storage is possibly a point worth referring to under this heading, and even if it were considered that the incorporation of stands in the undercarriage design would be too great an encumberance, the provision of suitable surfaces against which a jack or lever could bear would greatly facilitate the lifting operations, and enable blocks to be inserted to take the load off the tires.

Operation and Maintenance

The life of aircraft is a more vital matter in the case of machines required for civil purposes than in warfare. Fighting machines require to have all up-to-date improvements embodied in them at the earliest possible moment, and thus existing designs quickly become obsolete because they are out of date, rather than because they are worn out. Further, financial considerations affect civil aircraft very closely, as the rate of depreciation in value must be reduced as far as possible.

It is most important, therefore, that the question of wear and tear should receive attention at the time of design, and it is proposed to deal briefly with the conditions which largely contribute to depreciation, and to show how some of them may be ameliorated.

It is generally admitted that aircraft (excluding the engine itself) deteriorate more quickly when on the ground than when flying in the air. Especially is this so in the case of seaplanes, on which the effect of sea water is so pronounced.

Deterioration is to a very large extent attributable to atmospheric conditions, but it is considered that another important factor is that of damage and small accidents due to bad handling, climbing about the machine, and want of skill or care in the manipulation of the machine when on the ground and in the hangars.

The life of the engine itself naturally depends to a very large extent on the length of its working hours, periodic attention, etc., but at the same time it, too, may be considerably affected by the treatment and conditions to which it is subjected when not actually in use during flight.

The uses made of some of the structural members during handling or climbing about the machine would, if known to the designers, relieve them of a large amount of mathematical calculations. Such calculations are based on the assumption that the members and parts have to withstand only those stresses incurred in flying and alighting. As a matter of fact, parts which are amply strong on such an assumption may, and do, fail miserably under the unfair stressing they suffer during the handling of the machine on the ground.

It appears then that efforts will have to be made by designers to eliminate the liability of such "wear and tear" by utilizing fool-proof devices to meet such contingencies. It must be remembered that the handling of the machine or its components is most frequently carried out by unskilled labor. In the case of a covered component in which the principal members are hidden, it is necessary either to give precise directions for handling, or, better still, to make the operation fool-proof by the provision of handles. Attachments such as these need not necessarily be an encumbrance to the machine either from the point of view of weight or resistance, provided they are carefully considered when designing the component.

One does occasionally see notices on fuselages denoting where the weight can be taken to avoid damage to its members, but this is not a sufficient safeguard, as evidenced by an incident witnessed once by the author. Two men were assisting each other to lift at one point of a heavy fuselage, and they took particular care to lift it at equal distances on each side of the painted arrow denoting "lift here."

Provision of steps and treads, not only for entering the machine but also for the use of riggers and mechanics when carrying out adjustments, is essential, and if duly considered in the early stages of design would enable the designer to arrange for local stiffening in order to carry the loads imposed under such conditions.

As the operation of replenishing fuel, lubricant and water, and of adjusting the power plant, cannot usually be performed from the ground, it is mainly for these purposes that men climb on to aircraft. They treat axles, radius rods, exhaust pipes, and struts as platforms, and bracing wires, fairings, and the like as banisters. Apart from the question of unfair stressing, which has already been touched upon, the said objects are never really successful in these more humble capacities. Consequently there is every reason why proper handholds and footholds should be provided.

While dealing with the question of replenishing petrol, oil, and water—at present a rather long and highly inconvenient operation—a strong plea is put forward for larger filling and emptying apertures, and for their arrangement in less awkward situations. It is suggested that filling from underneath has many advantages, both as regards convenience and the avoidance of air locks in pipe systems.

The deterioration which may take place owing to atmospheric conditions demands considerable attention on the part of the designer, apart from the specifying of protective processes. These processes include painting, varnishing, pigmenting, a special process for metal parts, such as "Coslettizing" and "Sherardizing," and the use of non-corrosive materials. Attention should also be given to drainage arrangements in planes and fuselages, the sealing of hollow tube members, axles and struts, and the general avoidance of pockets and corners where moisture would collect. This is particularly important in the vicinity of glued-up wooden constructions such as ply-wood, built-up ribs and spars. These rely upon the strength of the glued joint for their rigidity, which is materially affected by the action of moisture.

In this connection it almost seems desirable that covers for exposed parts such as engines, propellers, and open cockpits, should be included in the design, and provision made for their accommodation in the machine. These essential accessories are rarely available when required, and the tendency is to provide them as an afterthought.

Repairs and Replacements

In view of the necessity of saving as much redundant weight as possible above that actually required to fulfil safety conditions in the design of aircraft, occasional minor accidents will inevitably occur when subjecting a machine to abnormal conditions such as landing in bad weather, or by forced landings in places with bad surfaces and obstructions.

To cope with such accidents it is necessary that the work of repairing machines should be facilitated as far as possible to avoid their being out of commission for unduly long periods, and to permit the damaged parts to be replaced without involving an excessive amount of work.

The designer can materially assist in arriving at such conditions by developing on standardization lines throughout the design. It is encouraging to note that great advances have been made in this country during and even previous to the war, as regards rigging attachments, piping connections, bracings, etc., and generally the smaller parts which are common to most types of aircraft, but there is still ample room for further development in other parts, such as fuselage sockets, plane attachments, wiring plates, struts and fittings, to name only a few.

Even in the case of complete components there appears to

be room for further standardization, and in one case this has been taken advantage of to a very large extent by arranging the design of the ailerons, elevators, and rudders so that they are all interchangeable. Such advances reduce the quantity of spares required, which is a very important item.

Apart from standardization of the parts themselves, the use of as few different sizes as possible of parts such as bolts, nuts, wires, fittings, etc., also reduces the spares difficulty, and at the same time reduces to a minimum the tool kit to be carried in the machine.

An advantage of standardization especially concerning rigging attachments which perhaps has been overlooked but which is considered to be of great value, is the fact that in making replacements the danger of substituting parts under the required strength is practically eliminated, as a part of incorrect size will not assemble on the adjacent fitting. It also has the advantage that in making new fittings, or verifying the strength of an existing fitting, the load to which the part should stand can be picked up from a knowledge of the strength of the standards without involving extensive calculations.

Repairs can also be facilitated by reducing to a minimum the amount of dismantling or stripping necessary to enable the replacement or repairing operation to be carried out. Particular offenders in this direction are continuous longerons, fittings which require to be slid on a member from the end instead of straddling it, fittings secured by rivets, or other permanent fixings, parts built up in position, and welded or brazed up structures. Seaplane hulls and floats are also typical instances where repairs are very extensive operations, even for rectifying the slightest damage.

One of the greatest liabilities to danger in making replacements is the difficulty of determining the correct material from which the replaced part should be made, and it is contended that in cases where high tensile steel is used some provision should be made to enable the material to be readily indentified. Indeed, any case of employment of a special material, not readily distinguishable at sight from that commonly used, calls for such treatment.

The author remembers one case where the designer had used a bolt of the standard dimensions, but in view of the excessive load which came upon it he had resorted to the use of a higher grade material to obtain the necessary strength. It happened that elsewhere on this particular machine there were standard bolts of the same size but of standard material. Naturally, at a later date, after overhaul, the bolts became mixed, and the structure collapsed in the air with fatal results.

The provision of instructional notices containing information as to piping and wiring diagrams, rigging dimensions, doping schemes, and warnings generally, placed in convenient positions on the machine, is invaluable to those who have to attend to repair and maintenance generally, and it is strongly urged that this practice be encouraged by the designers in order that their designs shall not be abused.

Bureau of Mines Bulletin

The Bureau of Mines, Department of the Interior, announces the publication of a bulletin on the methods of testing and specifications for lubricants adopted by the Committee on Standardization of Petroleum Specifications, and effective April 16, 1920.

These new specifications are based on specifications which have been in force in the War, Navy and other Departments of the Government, but the Committee has harmonized the various requirements of the different departments and has standardized and simplified the specifications and methods of testing so as to provide a uniform code for all Government departments and agencies.

The Committee wishes to call attention to two points in these specifications. The first is the method of grouping a large number of oils in three classes, A, B, and C. Class A comprises oils suitable for ordinary engine and machine lubricating; Class B, oils for high-speed engines, turbines, and dynamos, where an emulsion test is required; Class C comprises oils suitable for gasoline engines, motor cars, and air compressors, also oils which can be used as extra high grade turbine and dynamo oils. Oils of Class C meet requirements for carbon residue as well as emulsification tests.

Each of the three classes is divided into five grades, according to viscosity, known as extra light, light, medium, heavy and extra heavy, thus covering the bulk of the oils used by the Government. The other specifications refer to special oils and greases for particular purposes.

The second point to be noted is that specifications have been drawn on the basis of lubricating efficiency without reference to the sources of the oil. This leaves the refiner free to use any crude oil from which he can make satisfactory lubricants, and to adopt any process of manufacture he may find necessary.

The Technical Subcommittee is planning to hold an open meeting to discuss further specifications for petroleum products which may be necessary.

Copies of this bulletin may be obtained free of charge by addressing the Director of the Bureau of Mines, Washington, D. C.

THE FIRST GERMAN TWIN ENGINE AIRPLANE, DESIGNED BY O URSINUS, AND THE FORERUNNER OF THE GOTHA

The Claudel Carburetor

The Claudel carburetor, widely used in Europe for twenty years, is now made in America by the Claudel Carburetor Co., Long Island City, N. Y. This highly-perfected, plain-tube mixing device was designed by Charles Henri Claudel, the pioneer in the development of the plain-tube type of carburetor, who is recognized as the foremost European authority on carburetion

Records made by the Claudel carburetor in European racing before the was were both numerous and comprehensive, ninety-three first prizes being captured in 1913, in addition to the Indianapolis race and the breaking of all world's records on the Brooklands track in England. As a result, Claudel carburetors were employed extensively on the foremost Allied aviation engines from the beginning of the was in 1914 until the end. Among these were the Rolls-Royce, Sunbeam, Peugeot, Salmson, Hispano-Suiza and Renault.

Claudel carburetors made the first round trip across the Atlantic from England to America on the Sunbeam engines

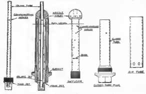


Fig 1 Diffuser of Claudel Carburetor in Section, and Its Components

of the British dirigible R-34 They were also used on the Rolls Royce engines of the Vickers-Vimy airplane which was the first plane to make a non-stop flight across the Atlantic The fact that this craft completed its long flight with one-third of its fuel unused is a striking commentary on the fuel-saving ability of the Claudel

Another record held by the Claudel carburetor is that for power and speed established by Sadi Lecointe, the famous French aviator, who set a new world's speed record of 232 miles per hour

Americanized in Design

The engineers of the Claudel Carburetor Co. have Americanized the European model of the Claudel to meet the particular requirements of engineering needs in this country They have added several features demanded by the American motorist, such as a quick starting device and rapid acceleration with a cold engine

The Claudel Carburetor

Early carbureting devices employed a spring-controlled air valve in an effort to secure the proper mixture balance throughout a wide range of engine speeds. In 1903 Charles Henri Claudel, of Paris, France, patented the first tube automatic compensating carburetor without the use of moving parts. His early principle of breaking up the gasoline by a swift current of air, making an emulsion inside the jet itself before delivery to the carburetor proper was original with him and has since been widely copied The modern Claudel retains the same principle, refined and improved to vaporize the heavy fuel of today

The Claudel Principle

The automatic functioning of the Claudel carburetor is based upon the action of the diffuser jet assembly This device combines three distinct principles of operation:

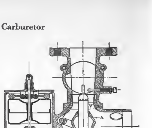


Fig 2. Section Through the Standard American Design of Claudel Carburetor

First—The orifice or jet which supplies all of the liquid fuel is placed at charge, or below the fuel level, where its flow is proportional to the difference in head.

Second—The diffuser proper is in "shunt" position, that is, enclosed in a chamber with openings at one end to the atmosphere and at the other end to the suction in the carburetor, thereby reducing the effect of the suction on the fuel flow

Third—Through the nozzle holes in the diffusor head the interior emulsion chamber of the diffusor is placed under the

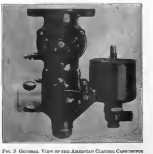


Fig. 3 General View of the American Claudel Carburetor

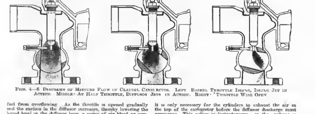
direct action of the vacuum in the carburetor, increasing the discharge as the vacuum is increased.

The combination of these three principles of operation, correctly applied, gives a balanced mixture exactly proportioned for the best results at every engine speed and load.

The Claudel is really a combination of two types of jet, one, the main jet, Fig. 1, of constant flow per unit of time, the other, shown as a series of nozzle holes, of suction-controlled flow Fig 1 indicates the fuel level when the carburetor is at rest. Fuel from the float chamber flows through the main jet into the diffusor, then through the compensating holes into the reservoir or diffusor bore It also flows through the idling jet into the idling tube, the level in the three tubes being the same as that in the float chamber

The Diffusor

Air at atmospheric pressure enters the outside base or air tube of the diffusor column, passes up this outer sleeve and over the top of the gasoline guard tube, which prevents the



Figs. 4—6 Diagrams of Mixture Flow in Claudel Carburetor. Left Barrel Throttle Idling, Idling Jet in Action. Middle At Half Throttle, Diffusor Jets in Action. Right 'Throttle Wide Open

fuel from overflowing As the throttle is opened gradually and the suction in the diffusor increases, thereby lowering the liquid level in the diffusor bore, a series of air bleed or compensating holes are progressively uncovered. Through these holes the air rushes into the ascending column of gas vapor and out the nozzle holes at the top of the diffusor in a finely broken-up gasoline emulsion. The higher the suction acting upon the diffusor, the lower will be the level of gasoline within it, and therefore, more of the compensating holes will be uncovered, permitting a greater dilution of the mixture.

At the higher speeds the diffusor is practically emptied and twenty-one spirally-arranged air bleed holes are in action. As the gasoline globules are lifted by the suction, they must pass through a barrage of twenty-one air guns shooting at right angles into the ascending fuel This turbulent mixing effect produces a finely divided fuel emulsion ideal for rapid flame propagation, extreme economy and high power The diffusor discharge is in approximately the ratio of fifteen parts of air to one part of gasoline by volume. This thorough intermixture of air and gasoline before it enters the carburetor barrel is the Claudel method of breaking up the heavy fuel of today for extreme economy

It will be easily seen that any kind of a power or consumption curve desired can be secured by changing the size and position of the compensating holes in the diffusor wall. For example, if the consumption curve shows a rich spot at an engine speed of 1000 r.p.m., the holes at this level of the gasoline in the diffusor could be enlarged, thinning out the mixture and bringing it to the point desired. In this way, an exact gasoline and air ratio can be maintained for the best results.

The clean, streamline interior of the Claudel plain-tube carburetor, with the barrel throttle giving an extended venturi effect, leaves no obstruction in the path of the charge and consequently full volumetric efficiency is secured. Also the gradual taper of the interior walls holds the mixture in uniform suspension and velocity.

The Idling Device

The idling device is incorporated in a central tube projecting up into the depression of the barrel throttle where a strong pull is exerted on the idling jet for low-speed action. The barrel throttle is slotted to pass around the idling jet and the only adjustment on the carburetor is a screw extending into the air space to partially block off the area of this slot as desired. Screwing it in lessens the air area and enriches the idling mixture. Screwing it out makes the mixture leaner.

Easy Starting Feature

In the American type of Claudel carburetor shown in Fig. 2, a decided improvement has been incorporated for strangling the air by means of a sliding air cone, controlled from the dash This device assures quick starting and warming up in cold weather, and *absolutely disregards temperature*. The streamline air cone, concentric with the diffusor, may be raised into contact with the venturi, shutting off the air supply and putting the full suction on the diffusor In this position it is only necessary for the cylinders to exhaust the air in the top of the carburetor before the diffusor discharge must commence. This action is instantaneous, as the volume is small

Referring again to Fig 2, the sliding cone *A*, in its closed or strangling position, fits snugly into the venturi entry *V*. The streamline shape of the cone centers and steadies the air stream so that it passes the nozzle holes of the diffusor with high velocity and in an even column ideal for the best results In its lowest position the cone offers no restriction to the maximum performance required and is of benefit in minimizing air intake turbulence.

In warming up a cold engine when a richer mixture is necessary, the cone *A* may be dropped slightly, forming a variable venturi With the cone in this restricting position one may readily get away while his engine is still cold Thus, in reality, the Claudel acts as a double carburetor—one of small venturi for normal driving, and, with lowered cone, another of full engine capacity.

The advantage of the Claudel cone over the common type of butterfly strangle valve, placed some three or more inches ahead of the fuel discharge nozzle, is very evident. In the latter type, all of the dead air lying between the nozzle and the strangler valve must be exhausted before fuel will begin to flow In the Claudel type, suction on the nozzle is instantaneous.

When the common type butterfly strangler is only slightly open (condition when warming up), the small amount of air passing the fuel discharge nozzle has little or no velocity and hence can pick up very little fuel Fuel, however, is discharged because of the greater pressure existing in the float chamber than in the mixing chamber, and instead of being picked up by the air, this raw fuel runs down to the butterfly strangler, where the air velocity is highest, there to be only partially vaporized and carried into the engine. In the Claudel type, on the other hand, an emulsion is discharged

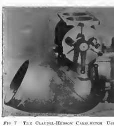


Fig 7 The Claudel-Hobson Carburetor Used on the Engines of the R-34

from the diffuser nozzle where it is immediately carried upward by the air entering at high velocity through the small, annular, streamline passage between the cone and the venturi.

Airplane Altitude Corrector

On the Claudel airplane carburetor the air cone, in much the same design, is used as an altitude corrector. Due to the lesser density of the air at high altitudes and the consequent lessened oxygen content of a given volume, it is not necessary to supply the same amount of gasoline for complete combustion as at ground level. Hence the flow of gasoline must be checked to secure the desired economy.

In the airplane Claudel, a venturi is installed several sizes in excess of the capacity required at ground level. The streamline cone is then raised and adjusted in the position of best performance at ground level. When the plane reaches an altitude of several thousand feet the pilot lowers the cone progressively as he ascends, enlarging the venturi, decreasing the suction on the diffusor and retarding its delivery. Full power is thus obtained without waste of fuel. This corrector has been used with great success on Claudel aviation carburetors during the last year of the was and subsequently

A High Grade Instrument

The Claudel is a very high grade carbureting instrument built in a number of standard S. A. E. vertical sizes. A horizontal model will be announced later. Special models, however, for special installations are built to order, including airplane and duplex designs.

Book Reviews

Applied Aerodynamics. By Leonard Bairstow (Longmans, Green and Co. 565 pp. with many illustrations and diagrams.)

The publication of Mr. Bairstow's book constitutes somewhat of an aeronautical event. Mr. Bairstow's reputation is perhaps, as high as that of any aerodynamicist. His many years work at the National Laboratory, his work during the war, as expert adviser in aerodynamics to the British Air Ministry, enables him to write with the highest degree of authority.

A great part of the book is based on research work, which Bairstow has himself carried out, or initiated.

The text-book on Applied Aeronautics, contains a full and adequate treatment of theory of flight, of dynamical stability, dynamical similarity, and other aspects of the science of Aeronautics. It contains perhaps the best published summary of all important wind tunnel work, which has been carried out in recent years, including the work done during the war. The treatment is simple and straightforward, even though the mathematics may at points be terrifying.

While Mr. Bairstow is perhaps more of a physicist than an engineer, he has consistently kept the needs of the engineer in view, and he has at the same time laid great stress on the limitations of accuracy in aerodynamical work.

These remarks give a general idea of the scope of the work. The book differs from many other publications in presenting original points of view. Even to the most hardened reader of aeronautical literature, every chapter, and sometimes every paragraph of a chapter, has special and original significance.

For example, it has been so long customary to assume an efficiency curve for the propeller, and the revolutions of the engine to remain constant under all conditions of flight, that the designer has almost forgotten the fundamental error involved in these assumptions. The author was, we believe, the first to plot the power required by the propeller at constant forward speed, and varying r.p.m., so getting a series of curves which can be co-ordinated with the engine horse power at varying r.p.m., whereby this error is removed.

In considering elementary aeronautical stability, an authoritative statement is given regarding the effects of downwash, and one of the curves given indicates the downwash on the tail plotted against the angle of incidence of the main wing.

Another interesting curve shown gives the angle of downwash at various distances from the biplane combination. There is a decided decrease in the angle of downwash on the tail plane the further away the tail plane is placed from the wings. An exponential formula of the variation is deduced which may be of considerable value in this direction.

Simple longitudinal balancing of the machine will always offer difficulties, because of the varying effects of downwash, but, if the results of the laboratories on downwash are carefully employed, a closer approximation in longitudinal balance seems nevertheless possible.

An interesting feature, which while fairly well-known, is sometimes lost sight of, indicates that while stability may be obtained by a negative tail setting with a fairly wide variation in the position of the center of gravity, nevertheless, the most stable machine is obtained when the center of gravity is far forward. When shifted further back, neutral stability is to be expected, and when the center of gravity shifts still further back, longitudinal instability must of necessity occur.

The chapter on the methods of measurements at aerodynamical laboratories, is perhaps of more specialized interest.

It is curious to see how the methods of measurements become simplified as time goes on. For instance, spindle corrections, a source of much former trouble, in the determination of the efficiency of a wing, disappear almost entirely by the simple method of suspending the airplane model or wing by a wire from the tunnel roof, and attaching another wire to the balance.

A very interesting elementary treatment is presented of the aerodynamical forces due to accelerated motion. While this has very little bearing on heavier-than-air craft, "virtual mass" due to acceleration plays an important part in the stability of the dirigible.

It is quite saddening to see that while Mr. Bairstow has all the aerodynamical data that are worth while at his command, there are still no definite values for the designer to trust to implicitly on biplane and triplane corrections, on full scale effects and other corrections. It still seems to be necessary to try out each new combination in the tunnel.

A study of the resistance of the airplane landing gear accentuates the importance of considering the effect of interference between parts. The resistance of the two wheels of a landing chassis is increased some 10 to 15 per cent when placed in position and interfered with by the rest of the chassis. The shock absorber on a standard type landing gear is found to have as much resistance as the wheels themselves. While the resistance of the entire landing gear is not so great as to be of paramount importance, yet these experiments open up a new line of thought, and engineers will soon realize that the resistance of parts when placed in disadvantageous juxtaposition, may be a serious cause of inefficiency.

One chapter is headed, "Aerial Manoeuvers and the Equations of Motion." While the author states that he has just touched the fringe of the subject, this chapter will be of fascinating interest. With painstaking methods of calculation, step by step integration and careful experimental work, it is quite possible to follow the airplane through at least simple maneuvers. Nothing but a serious study of this character will ever lead to a determination of stresses under all possible conditions.

It thus seems quite possible to calculate resistance derivatives for almost every possible condition. In view of the painful work involved in finding resistance derivatives experimentally, it seems to be quite necessary that methods of calculation for resistance derivatives should be developed as rapidly as possible.

A good deal of attention is given to air screws, and the treatment of their theory is perhaps as thorough as we have seen. In particular, the calculation of the forces on an air screw in yaw is very adequate. There are available some definite statements in the chapter on airscrews. For example rotational inflow being neglected, a value of .035 can be taken for the translational inflow factor where 1 is a measure of the total slip stream increase in velocity.

The chapter on fluid motion is treated in classical fashion. It is probably of less interest than any other portion of the book. While the treatment of dynamical similarity and scale effects presents anthing very new, it is interesting to read the treatment of a master hand.

Prediction and analysis of airplane performances have evidently been brought to a high pitch of accuracy by the British. While constructors do not always find it practical to go into the refinements outlined in the book, it would seem quite possible now to get a very exact estimate of performance in the initial stages of a design.

The chapter on stability is based mainly on Mr. Bairstow's own work. While the original papers are extremely difficult to read, notation and presentation are both improved in the book. There is a careful study of the manner in which gusts and other disturbances should be met by the controls. If it is possible to predict the exact action of the controls required under such conditions, it should subsequently be possible to design suitable automatical devices. The portion on disturbed motion makes somewhat difficult reading.

The Design of Screw Propellers. With Special Reference to their Adaption for Aircraft. By Henry C. Watts. 340 pp. Illustrations and Diagrams. (Longman's, Green and Co., New York.)

This is perhaps the most complete work on propeller design yet published, and is extremely well and authoritatively written. Development of the subject is based on a consistent theoretical outlook, thorough, mathematical to a large extent, yet not excessively so. The nomenclature is perhaps, somewhat clumsy, and will hardly appeal to American readers.

Beginning with the usual definitions, the book follows on with some data on the aerofoil. It would have been better perhaps, if Mr. Watts had given less consideration to somewhat out of data information in this chapter, on such subjects as changing the position of maximum ordinates, and given rather more examples of sections suitable for propeller work. A propeller designer needs as great a variety of good sections as is possible, and does not like to hunt for them in the original reports.

The simple Drzewiecki theory is well developed, and with this theory as a basis, factors effecting efficiency and torque are clearly stated. There are also given some useful curves based on this theory for all the blade elements of a propeller. This chapter will give even the beginner a coherent theory of propeller work, as a basis for subsequent refinement.

It is gratifying to see a very practical outlook in this book. For instance, Mr. Watts deals clearly with the change of engine revolutions with the speed of the aircraft. It is a simple fact, yet, not generally realized, that at maximum flying speed of an aircraft, the engine is giving its maximum power for the speed at which the propeller fitted will allow it to run. If the speed of the aircraft decreases, the angle of incidence increases, and the torque required to actuate the propeller at the same r.p.m., increases, so that the engine slows down, the angle of incidence then decreases, until a balance is obtained. It is points like these that are of even greater interest to the practical reader than rarefied mathematical theories.

The author states that the thrust coefficient cannot be obtained from full size trials. This is perhaps too pessimistic a view of the possibilities of the thrust meter. The thrust meter has perhaps been developed to a greater usefulness in this country than abroad. A simple method of obtaining torque and power coefficients from full flight tests is given.

We note for the first time, a Nomogram, connecting horse power, diameter, speed of propeller, and speed of aircraft.

Step by step, the Froude momentum theory is combined with the Drzewiecki, and a design carried out on the combined theory. The most important experimentation in regard to the combined theory is summarized.

There is a very complete consideration of overall efficiency. Mr. Watts is the first author to consider secondary overall efficiency, or efficiency when the airplane reduces its forward speed to flying, while the engine is maintained at full throttle.

Valuable rules are given on the calculation of the axial inflow velocity for routine design. These rules are based on considering the center portion of the propeller disc as ineffective, and equating the thrust to the change of momentum. As is customary with all British writers, one third of the inflow is considered as taking place ahead of the propeller. In considering flow through the propeller, it is interesting to see that towards the hub there are lines of flow in the reverse direction indicating a region of negative thrust. Streamlining the hub of the propeller may be quite a valuable help to efficiency. On slow air speeds it appears that the streamlines concentrate more about the axis of rotation than at high speeds. It is therefore to be expected that the resistance of a body placed behind the propeller, will have a greater effect on the propeller performance at slow speeds than at high, but the general conclusions drawn regarding the interference of a body on a propeller is that the interference effect is of the same character for all forward speeds, namely, interference increases both the thrust and efficiency and reduces the rotational speed of propeller and engine.

A very complete analysis of the strength of a propeller is given. A consideration of gyroscopic forces is included as well as one of the air and centrifugal forces. The method is perhaps a little too complex for routine design.

The author indicates how a propeller with a straight leading edge may lead to tension on the glued joints, a point which is of great importance on propellers to be used in hot climates.

In considering geared motors, the author is strongly of the opinion that gearing will be worth while only for comparatively large powers.

We fully agree with the author in his conclusion that there are very few points in favor of the four bladed propeller. With a four bladed propeller, the efficiency is decreased, the equivalent body diameter is increased relative to the propeller diameter, the material used in manufacture is increased by about 50 per cent and the difficulties of packing and transporting are increased. The advantages of the four bladed propeller appear to be greater strength and smoother running.

Some interesting conclusions arrived at on the tandem propeller are summarized herewith:—

1. The efficiency of working of the following propeller is reduced by the slipstream of the leading propeller.

2. The efficiency of the tandem combination is increased by rotating the propellers in opposite directions. In a particular case tested the efficiency of the combination was increased by about 4 per cent under climbing conditions, assuming the two propellers to be giving the same thrust and that the performance of the leading propeller is not appreciably affected by the working of the following propeller.

3. The performance of the front propeller is only slightly modified by the working of the following propeller.

4. It would appear advantageous to use propellers of different diameters, the larger propeller leading.

The generally accepted conclusion that a variable pitch propeller will enable the revolutions to be kept constant from maximum speed to climbing speed and to maintain the revolutions with altitude, is arrived at by deduction.

The Lift of Hydrogen

By Squadron Leader P. L. Teed, R. A. F.

The term Lift as applied to airships is equivalent to buoyancy, and like buoyancy, when applied to water-borne ships, it depends on two considerations —

(1) The weight of the ship

(2) The weight of supporting medium displaced by the ship

Here the analogy between water and air borne craft ceases. For in the case of water-borne ships (other than the submarines) a condition of equilibrium always prevails, if the weight of the ship is increased its displacement is increased, the water line being altered, but a state of equilibrium continues.

The airship, being entirely surrounded by the supporting medium, has no equivalent to the alteration in water line producing equilibrium. With change in weight of the displaced supporting medium the airship may possess either positive or negative buoyancy

While the structural weight of the ship remains constant, the weight of medium displaced by the ship is subject to considerable variation

The following affect the buoyancy·

(1) The volume of gas in the airship
(2) The purity of the gas.
(3) The barometric pressure of the air
(4) The temperature of the air
(5) The amount of water in the air

Of the five matters affecting the lift of an airship apart from its volume, the purity of the gas is generally to be taken to be the most significant factor, but the combination of temperature and barometric pressure may produce even more important variations.

The maximum purity of hydrogen in an airship does not exceed 98 per cent by volume, while certain chemical considerations necessitate the deflation of the airship at 80 percent by volume

Under mean atmospheric conditions, viz, temperature 55 deg Fahr. and barometer 29.5 in., the lift of 1,000 cu ft. of hydrogen at 98 per cent purity is 69.7 lb., while under the same atmospheric conditions at 80 percent purity it is 56.8 lb.—a variation of 12.9 lb per 1000 cu. ft. of volume

Now turning to purely atmospheric effects, 1,000 cu. ft. of 98 per cent pure hydrogen at a barometric pressure of 31 in. and at a temperature of 20 deg Fahr gives a lift of 78.6 lb while an equal volume of gas of the same purity at a barometric pressure of 28 in. and a temperature of 80 deg Fahr gives a lift of 63.2 lb., a variation of 15.4 lb per 1,000 cu. ft. of volume

Having illustrated the variations in lift due to (1), purity, and (2), to atmospheric changes, it is perhaps permissable to state that while the lift of 1,000 cu. ft of hydrogen 98 per cent pure at a temperature of 20 deg Fahr and under a barometric pressure of 31 in. is 78.6 lb, the lift of 1,000 cu. ft. of hydrogen 80 per cent pure at a temperature of 80 deg Fahr and under a barometric pressure of 28 in. is 51.5 lb, a variation of 27.1 lb per 1,000 cu. ft., which represents the extremes of purity and atmospheric conditions which may easily be met with

Having dealt with the general principles of lift and illustrated its variations by some examples, the question will now be dealt with in detail

Purity of the Gas

It is customary to give the chemical composition of the hydrogen in an airship as so many per cent pure. This term requires definition *By the percentage of purity of hydrogen is meant the percentage of hydrogen contained by volume, assuming the impurity to be of the same density as air.*

Now it will be seen that if the impurity in the hydrogen is air, then since air in air is without weight, the relative lift of equal volumes of impure hydrogen under the same atmospheric conditions is in the same ratio as their hydrogen contents (by volume). To sum up *The lift of unit volume is directly proportional to purity*

Alteration in Lift by Barometric Change

One thousand cubic feet of pure hydrogen at 30 in. barometric pressure and a temperature of 40 deg. Fahr. weighs 5.55 lb. 1,000 cu. ft. of dry air under the same atmospheric conditions weighs 80 lb Therefore, on the basis lift is the difference between displaced weight and displacing weight

80 — 5.55 lb = Lift of 1,000 cu. ft. of pure hydrogen at 30 in. Barometer and 40 deg Fahr.
= 74.45 lb.

Now assume that the temperature remains constant but that the barometer changes to 31 in. Then by the application of Boyle's Law it will be seen that

$$\frac{80 \times 31}{30} - \frac{5.55 \times 31}{30} = \text{Lift per 1,000 cu. ft. of 100 per cent pure hydrogen at 31 in. Barometer and 40 deg. Fahr.}$$
$$= 82.6 - 5.73$$
$$= 76.93 \text{ lb}$$

But the above is an unnecessarily complicated way of arriving at the desired result, for the mathematical expression may be simplified to —

$$\frac{31}{30}(80 - 5.55) = \frac{31}{30}(74.45)$$
$$= 76.93 \text{ lb}$$

But 74.45 lb is the lift of 1,000 cu ft. of hydrogen 100 per cent pure at 30 in. barometer and 40 deg Fahr.

Therefore the rule may be expressed. *The Lift of the unit volume is directly proportional to barometric pressure.*

Alteration in Lift by Thermometric Change

By the direct application of Charles' Law it can be shown that *Lift of unit volume is inversely proportional to the absolute temperature.*

To summarize the three rules which have already been stated:

(1) Lift of unit volume is directly proportional to purity.
(2) Lift of unit volume is directly proportional to barometric pressure.
(3) Lift of unit volume is inversely proportional to absolute temperature.

From the above the following formula may be deduced to give the lift of 1,000 cu. ft. of hydrogen under any condition of purity, temperature or barometer

$$\text{Lift per 1,000 Cu. Ft. in lbs.} = \frac{74.45 \times \text{per cent purity} \times \text{barometer} \times 900 \text{ in inches}}{100 \times 30 \times (460 \text{ plus temperature in degrees Fahr.})}$$
$$= \frac{12.41 \times \text{per cent purity} \times \text{barometer in inches}}{460 \text{ plus temperature in degrees Fahr.}}$$

The Temperature of the Gas

In the formula which has been given it has been assumed that the temperature of the gas is the same as the temperature of the air—a condition which generally prevails in the airship shed, but during flight there is frequently a material difference in temperature between the two. This difference arises in two ways

(1) The effect of sun on the gasbag
(2) The effect of a quick descent after flying for a considerable time at a high altitude.

In the first case the sunlight striking the gasbag fabric causes this to rise above the air temperature, the heat being in course of time transferred to the gas itself. The gas then expands in accordance with Charles' Law Now in rigid airships if the gasbag is not full, or in non-rigid ships if there is air in the ballonets, this expansion will cause a greater volume of air to be displaced and consequently an increase in lift to take place.

For example At 40 deg. Fahr. and 100 percent purity

1,000 cu. ft. of hydrogen weighs 5.55 lb., and 1,000 cu. ft. of air under the same atmospheric conditions weighs 80 lb. Hence the lift per 1,000 cu. ft is:

$$80 - 5.55 \text{ lb.}$$
$$= 74.45 \text{ lb.}$$

Now assume that the temperature of the gas rises to 50 deg Fahr. Its volume instead of being 1,000 cu. ft. will be:—

$$\frac{1{,}000 \times 510}{500} \text{ Cu. Ft.}$$
$$= 1{,}020 \text{ Cu. Ft}$$

But its weight is still 5.55 lb., although the weight of air displaced is not the same; for instead of 1,000 cu. ft. being displaced, 1,020 cu. ft. are displaced, which weigh:

$$\frac{80 \times 1{,}020}{1{,}000} \text{ lb}$$
$$= 81.6 \text{ lb}$$

So the lift of the original 1,000 cu. ft. of gas becomes:

$$81.6 - 5.55 \text{ lb.}$$
$$= 76.05 \text{ lb}$$

This alteration in lift by difference in temperature of the gas may at first sight appear to be of mere academic interest, but in large airships this is certainly not the case. Take the case of a Zeppelin of 1,250,000 cu. ft. maximum capacity containing only 1,000,000 cu. ft. of hydrogen. The ship is flying in equilibrium when the sun comes out and causes the gas temperature to rise from 40 deg Fahr. to 50 deg. Fahr. Then, as has already been seen, the lift of the gas is increased 1.6 lb for every thousand feet of gas in the ship at 40 deg. Fahr., but the volume of gas was assumed to be 1,000,000 cu. ft. therefore the lift of the ship will be increased

$$1000 \times 1.6 \text{ lb.}$$
$$= 1{,}600 \text{ lb.}$$

This alteration in lift during flight of large airships is of considerable importance, and it is consequently necessary that the pilot should always be acquainted with the relative temperature of the gas and air, for which purpose electric thermometers are now fitted inside the gasbag, recording in the car.

The Amount of Water in the Air

Though it may not appear of importance, the humidity of the atmosphere has a certain effect on the lift of hydrogen. The greater the amount of water vapor in the atmosphere the less the weight of unit volume of air consequently the less the lift of unit volume of hydrogen, for the difference between displaced and displacing weight is less.

This alteration in lift due to humidity is not very material, as it does not generally cause a difference in lift of more than 3 lb. per 1,000 cu. ft. of gas. However, in the case of "lift trials" some adjustment must be made for humidity. This adjustment can most easily be made by observing the difference in temperature between the wet and dry thermometer and then employing an empirically compiled table which gives the necessary adjustment per 1,000 ft. of gas.

The Lift of Airships

So far the lift of hydrogen and the phenomena which affect it only have been dealt with. Now the lift of airships will be considered. Before dealing with this, two terms require definition: one, Available Lift, the other, Disposable Lift. Available Lift is the total lift of the gas in the airship. Disposable Lift is the difference between the available lift and the fixed weight of the airship The Disposable Lift is that buoyancy which is available for carrying fuel, oil, crew and ballast.

As will be seen, both the Available Lift and the Disposable Lift will vary with temperature, barometer, humidity and purity. Consequently a custom has originated in classifying airships on their available lift, assuming the ship to be 100 per cent full, with hydrogen 95 per cent pure, the barometer being 29.5 in., the thermometer 55 deg Fahr and the air dry

From the formula for lift already given, or by means of the Scott-Teed Slide Rule, it can be calculated that the lift of gas under these conditions is 67.7 lb. per 1,000 cu. ft. Thus the tonnage of existing classes of English airships are.—

S. S. class $\frac{60 \times 67.7}{2240}$ tons = 1.81 tons.

C. P. class $\frac{185 \times 67.7}{2240}$ tons = 5.59 tons.

N. S. class $\frac{360 \times 67.7}{2240}$ tons = 10.88 tons.

In building airships their Disposable Lift under the conditions of purity, humidity, barometer and temperature already mentioned is generally specified but when the Disposable Lift is taken practically, it is improbable that all, if any, of the specified conditions exist, consequently the practically obtained figure must be converted by simple mathematics to what it would have been had the conditions of the specification prevailed.

To convert Disposable Lift from one set of conditions to another the following must be known.—

(1) Disposable Lift on the occasion of the trial.
(2) Temperature on the occasion of the trial
(3) Purity of Gas on the occasion of the trial
(4) Barometer on the occasion of the trial
(5) Humidity of the air on the occasion of the trial
(6) Volume of the gas. or fixed weight of ship on the occasion of the trial.

To take an example: Let it be assumed that by practical trial 9 tons was found to be the Disposable Lift of a 1,000,000 cu. ft. airship, 100 per cent full of hydrogen 98 per cent pure, when the barometer was 30 in., the temperature 40 deg. Fahr., and the humidity of the atmosphere negligible. It is required to know what would be the Disposable Lift under the generally specified conditions, namely 100 per cent full of hydrogen, 95 percent pure, when the barometer is 29.5 in. the temperature 55 deg. Fahr., and the humidity negligible.

The first thing to be done is to determine the total lift on the occasion of the practical trial.

By means of the Lift Formula already given, or by means of the Scott-Teed Slide Rule, determine the lift per 1,000 cu. ft. of gas on the occasion of the trial. This will be found to be : 73.0 lb. per 1,000 cu. ft.

Now the volume of the ship is known to be 1,000,000 cu. ft.

Therefore $\frac{73 \times 1{,}000}{2240}$ tons is the Available Lift,
$= 32.59$ tons.

Now the Disposable Lift of the ship was found by trial to be 9 tons.

Therefore 32.59 — 9.0 tons is the weight of the ship.
$= 23.59$ tons.

Now by means of the formula or slide rule determine the lift per 1,000 cu. ft. of hydrogen under the conditions of the specification. This will be found to be:—

67.7 lb

Therefore under the conditions of the specification

$\frac{67.7 \times 1{,}000}{2{,}240}$ tons is the Available Lift,
$= 30.22$ tons.

But the fixed weight of the ship was found to be 23.59 tons.

Therefore 30.22 — 23.59 tons is the Disposable Lift under specified conditions.
$= 6.63$ tons.

If the fixed weight is known but not the volume.

In the example which was taken the volume of the ship was known but not its fixed weight. Now let it be assumed that the weight was known but not the volume. Under these circumstances, if in other respects the same problem was to be solved, the procedure would be·

Determine the lift per 1,000 cu. ft. on the occasion and circumstances of the trial. This would be: 73 lb. per 1,000 cu. ft

Now the weight of the ship was known to be 23.59 tons.

Therefore 23.59 plus 9 tons is the Available Lift of the ship,
$= 32.59$ tons.

Therefore $\frac{32.59 \times 2240}{73}$ thousand cubic feet is the volume of the ship.

= 1,000 thousand cu. ft.
= 1,000,000 cu. ft

If neither volume nor fixed weight are known.

Occasion may arise when it is desired to know the Disposable Lift of an airship when the conditions of the specifications do not exist and neither the volume nor the weight of the ship is known.

Let it be assumed that on the occasion of the practical trial the Disposable Lift was found to be 9 tons when the ship was 100 per cent full of gas of 60 per cent purity and the barometer was 29.8 in. and the temperature 30 deg. Fahr.

Determine the lift of 1,000 cu. ft. of hydrogen under these circumstances by formula or rule. It will be found to be 72.5 lb.

When this has been done, it is necessary to wait until some of the conditions have altered. Assume on a later occasion that the ship is 100 percent full with hydrogen 95 per cent pure, when the barometer is 28.5 in. and the temperature 60 deg. Fahr. Take the Disposable Lift, which for purposes of argument will be assumed to be 5 tons.

Then work out the lift per 1,000 cu. ft. of hydrogen under the conditions prevailing.

This will be found to be .

64.7 lb. per 1,000 cu. ft.

Between the first and the second trial the Disposable Lift has altered from 9 tons to 5 tons, and the lift per 1,000 cu. ft. from 72.5 to 64.7 lb.

Now the difference per 1,000 cu. ft. in lift on the two occasions is 72.5—64.7 lb. = 7.8 lb.

The difference in Disposable Lift, 9—5 tons.

= 4 tons = 8960 lb.

Therefore since the fixed weight of the ship has remained constant, $\frac{8960}{7.8}$ is the volume of the ship in thousands of cubic feet,

= 1148.7 thousand cu. ft. = 1,148,700 cu. ft.

The volume being now determined, from the methods already described it is possible to calculate the Disposable Lift under any conditions whatever.

To summarize, the following are necessary for the conversion of Disposable Lift

Under Conditions of Lift Trial

Available Lift 100 per cent full — Disposal Lift found = Fixed Weight.

Under Conditions to Which Disposable Lift Is to Be Converted

Available Lift 100 per cent full — fixed weight = Disposable Lift.

Since this memorandum was written, very accurate determinations of the relative weights of hydrogen and dry air have been made by the British National Physical Laboratory with the result that the lift of 1,000 cu. ft. of hydrogen at 30 in. barometric pressure and at a temperature of 40 deg. Fahr. has been found to be 74.06 lb. consequently the lift formula should be

$$\text{Lift per 1,000 cu. ft} = \frac{12.34 \times \text{per cent purity} \times \text{bar. in inches}}{400 \text{ plus Temperature in degrees Fahr.}}$$

The Scott-Teed Lift Slide Rule has been altered in accordance with this determination.

N. A. C. A. Reports

CONSTRUCTION OF WIND TUNNEL MODELS. Synopsis of Report No. 74, National Advisory Committee for Aeronautics.

This report gives a full description and discussion of the best methods to be employed in constructing models of aircraft and parts thereof for testing in wind tunnels. It includes material on the construction of model aerofoils, of fuselages, and of tail surfaces, and also on the types of models to be used for such special tests as those on pressure distribution. The amount of detail which it is desirable to include on a wind tunnel model is discussed, and the means of approximating the resistance of radiators and other appendages without constructing geometrically similar models are treated. In short, the report is a general handbook on the subject, and is designed to eliminate the difficulties which airplane designers often experience in obtaining models suitable for wind tunnel use.

AIRPLANE RANGES AND USEFUL LOADS.—Synopsis of Report No. 69. National Advisory Committee for Aeronautics.

This report considers the question of possible ranges and useful loads for airplanes from two points of view. A sample calculation is made using a step-by-step method and a theoretical solution is carried through and the two results compared. It is shown that the two methods check each other in a very satisfactory way which is fortunate as the theoretical formulas may be used with confidence and their numerical application is a very simple matter.

It is quite evident that the factors upon which large range depends are the lift over drift ratio for the complete machine, the ratio of weight empty to weight fully loaded, the fuel consumption per horsepower hour of the motor and the efficiency of the propeller. The qualities of an airplane are completely characterized by these factors. The theoretical solution gives explicitly the way these factors contribute to its range and load carrying properties.

The question of range with useful load is considered including a flight to an objective, delivery of load and return without refueling, this problem being of interest with respect to bombing. It is completely solved and a very practical and expeditious method is derived for all possible cases. Among other results are equations giving-time to attain a given distance-time required to use up a given weight of fuel and distance corresponding to a given weight of fuel. The effects of climb at start and glide at end of flight are shown to be practically negligible.

Comparisons of high speed flight and flight with minimum power are made with greatest range or economical flight, especially with regard to load carrying range and time. A special method for determining the effect of the wind from a single curve for all wind speeds either with or against the direction of flight is derived and applied and the effect of wind on angles of incidence for most economical flight is determined. Most of the formulas are applicable not only to range flights at most economical angles but also flight at any angle of incidence.

ANALYSIS OF FUSELAGE STRESSES.—Synopsis of Report No. 76, National Advisory Committee for Aeronautics.

This report, prepared by the staff of the National Advisory Committee for Aeronautics at Langley Field, is concerned chiefly with the assumptions to be made as to the loading on fuselages. A typical "stick-and-wire" fuselage is analyzed for different sets of assumptions as to landing loads and for three different conditions in flying. In treating flying conditions, all the inertia loads are included and a single stress diagram is drawn including all the members from nose to tail. The inertia loads due to angular accelerations are shown to be very important and to decrease the stresses in the rear of the fuselage by more than 50 per cent in some instances.

The discussion of stress analysis by graphical methods, is, of course, applicable only to "stick-and-wire" fuselages, but the treatment of inertia, damping, and tail loads is equally useful for veneer and monocoque designs. As a result of this investigation of loads certain recommendations are made as to the distribution of loads in sand-load testing of fuselages.

Copies of these reports may be obtained upon request from the National Advisory Committee for Aeronautics, Washington, D. C.

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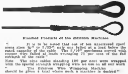

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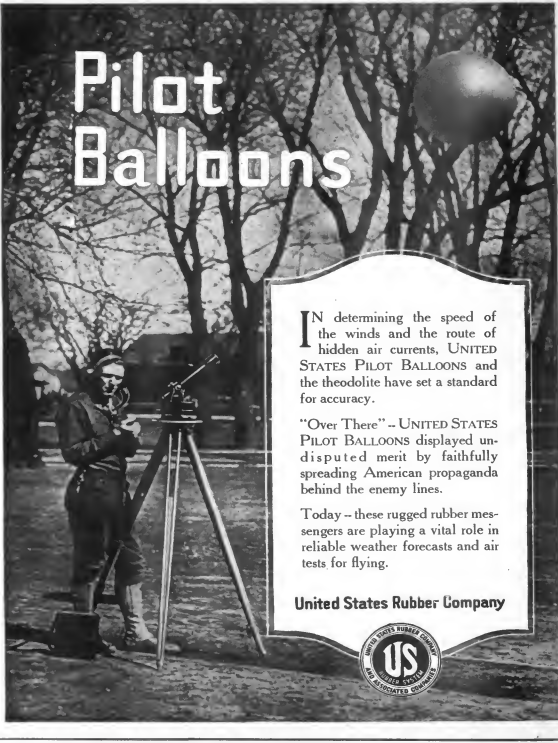

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